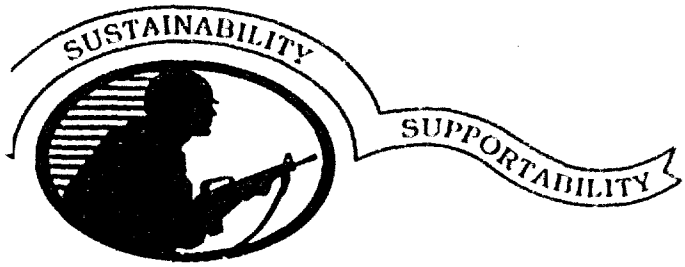

TECHNICAL REPORT
NATICK/TR-93/004

AD _____

REPLACEMENT OF COCONUT OILS WITH UNSATURATED OILS IN RECOMBINED FILLED MILK

by
I.J. Jeon
H.A. Roberts

Kansas State University
Manhattan, KS 66506

and
A.G. Senecal*

October 1992

Final Report
April 1990 - May 1991

PREPARED FOR
UNITED STATES ARMY NATICK
RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
NATICK, MASSACHUSETTS 01760-5000

*FOOD ENGINEERING DIRECTORATE

DISCLAIMERS

The findings contained in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of trade names in this report does not constitute an official endorsement or approval of the use of such items.

DESTRUCTION NOTICE

For Classified Documents:

Follow the procedures in DoD 5200.22-M, Industrial Security Manual, Section II-19 or DoD 5200.1-R, Information Security Program Regulation, Chapter IX.

For Unclassified/Limited Distribution Documents:

Destroy by any method that prevents disclosure of contents or reconstruction of the document.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 1992	FINAL APRIL 1990 to MAY 1991

4. TITLE AND SUBTITLE
REPLACEMENT OF COCONUT OILS WITH UNSATURATED OILS IN RECOMBINED FILLED MILK

5. FUNDING NUMBERS
PR: MSR 1522
C: DAAK60-85-C-0042

6. AUTHOR(S)
I.J. JEON, H.A. ROBERTS and A.G. SENECAL*

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Department of Animal Sciences & Industry
Kansas State University
Manhattan, KS 66506

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Natick Research, Development and Engineering Center
Kansas Street ATTN: SATNC-W
Natick, MA 02170-5018

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NATICK/TR-93/004

11. SUPPLEMENTARY NOTES
*Professional Affiliation: U.S. Army Natick Research, Development and Engineering Center Food Engineering Directorate

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words) Government Owned, Contractor Operated milk plants are using coconut fat in the production of recombined filled milk at military bases abroad. Consumer concerns regarding elevation of serum cholesterol by saturated fats has resulted in studies to replace coconut fat with less saturated vegetable fats. This research was conducted to formulate a filled milk product utilizing combinations of fats and emulsifier/stabilizers that would posses characteristics equal to the coconut oil based product. Effect of emulsifying/stabilizing agents and vegetable fats on off-flavors/odors, mouthfeel, milk flavor and acceptability was investigated. Preliminary studies with combinations of eight partially hydrogenated fats and four emulsifier/stabilizers demonstrated that the sensory characteristics of filled milk were affected by the type of fat and emulsifying/stabilizing agents used. The formulations which preformed the best were Canola/D22B, Canola/Mono-and Diglycerides, Sunflower HB95/D22A and Cottonseed/D22C. These formulations and a 50:50 blend of Canola/D22B and HB95/D22A were further tested for their effects on physical, chemical and sensory characteristics of filled milks during refrigerated storage. All formulations were stable to lipid oxidation. There were no significant differences in overall acceptability due to the small size of the expert milk panel.

14. SUBJECT TERMS			15. NUMBER OF PAGES
RECOMBINED FILLED MILK	EMULSIFIERS	PRODUCTION	37
VEGETABLE OILS	STABILIZERS	ACCEPTABILITY	16. PRICE CODE
TEST AND EVALUATION	FAT SUBSTITUTES	MILK	

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

LIST OF CONTENTS

LIST OF TABLES

PREFACE

The research described in this report was conducted at the Department of Animal Sciences and Industry, Kansas State University, Manhattan, Kansas. Research activities took place during the period 5 April 1990 through 17 May 1991. This report presents data indicating that coconut oil in filled milk formulations can be replaced with a partially hydrogenated vegetable oil or a blend of the vegetable oils in conjunction with appropriate emulsifiers and stabilizers. The data in this report were evaluated by investigators at Kansas State University under a contractual agreement (Contract Number DAAK60-90-C-0018) with the U.S. Army Natick Research, Development and Engineering Center, Food Engineering Directorate.

Human subjects involved in this study were sensory panel members, who participated in the product evaluation after giving their free and informed voluntary consent. The panel participation was classified as no more than minimal risk under the expedited review procedure authorized in 45 Code of Federal Regulations 46:110 #9.

Citation of trade names in this report does not constitute an official endorsement or approval of the use of such items. Dr. Andre Senecal, of the Food Engineering Directorate at Natick, was project officer for this report.

ACKNOWLEDGEMENTS

The authors wish to express their sincere appreciation to Mr. Juan Cordon for his genunine effort in conducting this research as a graduate student at Kansas State University. The authors also wish to thank Mr. Petros A. Levis and his crew for their help in preparing and processing filled milk samples at Kansas State University Dairy Processing Plant. We are grateful to Dr. Andre G. Senecal, U.S. Army Natick Research, Development and Engineering Center, Natick, MA, for his understanding and coordination as project officer. We are indebted to Dr. Senecal for his part of research for selecting most vegetable oils and testing their stability prior to this investigation. We also would like to thank the members of our sensory panel who participated unselfishly in evaluating milk samples throughout the study. Without their participation, this study would not be possible. The authors also wish to extend an appreciation to all ingredient suppliers who showed a genuine intrest in this research.

SUMMARY

The objective of this research was to determine the most adequate oil, or blend of oils, which would replace the current coconut oil used in filled milk product at Government Owned Contractor Operated milk plants. The goal of the research was to formulate a product with a combination of vegetable oils and emulsifiers/stabilizers that would possess equal to or better characteristics than coconut oil. To achieve the objective, eight partially hydrogenated and one non-hydrogenated vegetable oil as well as four different emulsifying/stabilizing agents were selected. Preliminary studies were conducted by testing each vegetable oil against each emulsifying agent in a filled milk formulation for sensory characteristics. The effect of emulsifying/stabilizing agents and oils on such characteristics as off-flavors/odors, mouth-feel, overall milk flavor, and acceptability was investigated. The four most probable combinations of oils and emulsifiers/stabilizers were selected from preliminary studies. These formulations were Canola/D22B, Canola/Mono- & diglycerides, Sunflower HB 95/D22A, and Cottonseed/D22C, and were further tested for the effects on physical, chemical, and sensory characteristics of filled milks during storage. Two formulations, Canola/D22B and a 50/50 blend of Canola/D22B and Sunflower HB 95/D22A, were selected and further evaluated organoleptically over a two-week period. The filled milk formulation with the most desirable sensory characteristics was determined.

Results showed that the type of vegetable oil and emulsifying/stabilizing agent affected the flavor, odor, mouth-feel, and ultimately the acceptability of filled milk. The formulation containing Sunflower HB 95/D22A possessed the best overall milk flavor, the least amount of off-flavors/odors and the highest acceptability during the first week of storage, but deteriorated considerably after one week. The 50/50 blend, although not significantly different from formulations containing Canola/D22B and Sunflower HB 95/D22A, was observed to improve slightly with time in its mouth-feel, but not in off-flavors/odors, overall milk flavor, or acceptability. The formulation containing Canola/D22B, however, possessed an acceptable milk flavor and aroma during week one of storage and improved slightly during week two and remained stable thereafter. Phytochemical analysis suggested that the formulations with Canola/D22B, Canola/Mono- & diglyceries, Sunflower HB 95/D22A, and Cottonseed/D22C were stable to lipid oxidation during storage and the levels of fat separation were within acceptable limits.

REPLACEMENT OF COCONUT OIL WITH UNSATURATED OILS IN RECOMBINED FILLED MILK

INTRODUCTION

In the past two decades, imitation and filled milk products have shown some success in replacing their real milk counterparts in America as well as in Europe (Mann, 1988). However, the quantity consumed is extremely small compared to the consumption of milk products. Coconut oil, the main oil in many parts of the world, was used traditionally as a milk fat replacement in most filled milk formulations. The concern about elevation of serum cholesterol level by saturated fats and oils has led to attempts to replace coconut oil with less saturated vegetable oils.

Modler et al (1970) investigated the use of several vegetable oils in filled milk formulations. Their study showed that, after one week of storage, the levels of oxidation and, consequently, oxidized flavor, in formulations containing safflower, corn, cottonseed, peanut, and olive oils were far too objectionable. However, the formulation made with lightly hydrogenated soybean oil was found to be acceptable, although it exhibited a mild oxidized flavor as well. Recently, a filled milk formulation, called a healthy alternative to whole milk, "Fit 'n' Lite" (Pritchitt Foods, UK), was introduced successfully in Europe. It was reportedly formulated with sunflower oil (Lane, 1986). Using a similar concept, a frozen filled milk concentrate was developed by scientists in the U.S. Department of Agriculture (Kinzel, 1990). Although not commercially available, the frozen milk concentrate when fully reconstituted would contain a minimum of 8.25% nonfat milk solids and up to 2% vegetable oil (soybean, corn, or peanut oil).

Emulsifiers are commonly used in filled milk products to keep oils dispersed in the milk system. Bundus (1970) reported that different types of emulsifying agents improved the flavor and mouth-feel (by affecting the body) of a filled milk product. However, little information is available about the effect of stabilizers and a combination of emulsifiers and stabilizers on flavor and textural characteristics of filled milk.

OBJECTIVE

The objective of this study was to determine the most adequate oil, or blend of oils, which would replace the current coconut oil used in filled milk product at Government Owned Contractor-Operated milk plants. The goal of the research was to formulate a product with a vegetable oil or a combination of vegetable oils and emulsifiers that would possess characteristics equal to or better than coconut oil.

EXPERIMENTAL PROCEDURES

Eight partially hydrogenated vegetable oils and four different emulsifiers/stabilizers were selected for this study. All vegetable oils except Natural Sunflower and Cottonseed oils were selected based on storage stability tests performed at the U.S. Army Natick Research, Development and Engineering Center in Natick, Massachusetts. All oils (except Natural Sunflower) used had Active Oxygen Method (A.O.M.) values of not less than 100 hours. Three emulsifiers used were a mixture of stabilizers in addition to mono- and diglycerides, while the other was a mixture of mono- and diglycerides. The three emulsifier/stabilizer mixtures (pre-blended) used were Actoloid D22 Type A, B, and C. The Actoloid D22A was composed of mono- and diglyceride, sodium caseinate, soy protein, carrageenan, and sodium citrate. The Actoloid D22B was composed of mono- and diglyceride, soy protein, whey protein, carrageenan, sodium citrate, and disodium phosphate. The Actoloid D22C consisted of mono- and diglyceride, sodium caseinate, carrageenan, and sodium citrate. Refer to appendix, Tables A-1 and A-2 for a list and source of the vegetable oils and emulsifiers/ stabilizers used.

A. Formulation

The filled milk formulation consisted of four basic components: water, nonfat dry milk (NDM) (low heat), vegetable oil, and emulsifier and/or stabilizer. The percentages of each of the components for the formulation used throughout the entire study are shown below.

Water	88.20%
NDM	8.25%
Oil	3.25%
Emulsifier/Stabilizer	0.30%
	100.00%

The sequence in which these components were incorporated was as follows: In formulations where mono- and diglycerides were used, (1) the NDM was dispersed in water between 60-90°F and once fully dispersed the temperature of the mixture was brought up to 130°F; (2) the mono- and diglycerides' flakes were dissolved in with the melted oil at 120°F; (3) the oil (containing the emulsifier) was blended in with the NDM mixture between 120-130°F; and (4) the mixture was agitated for approximately 10 minutes and subjected to vat (preliminary study only) or high-temperature-short-time (HTST) pasteurization. The milk was cooled, packaged and stored at 35°F. In formulations where Actoloids D22A, D22B, or D22C were used, (1) the emulsifier/stabilizer blend was dry blended with the NDM and dispersed in water at 60-90°F and subsequently brought up to 130°F; (2) the melted oil (at 120°F) was blended in with the NDM and stabilizer mixture; and (3) the mixture was agitated for 10 minutes, pasteurized, packaged and stored.

B. Experimental Approach

Stage-one experiment involved with the evaluation of all the possible combinations of eight oils and four emulsifiers/stabilizers as listed in Tables A-1 and A-2. Sunflower Natural was not evaluated against mono- & diglycerides because this particular oil was not available at that time and therefore resulted in a total of 31 different formulations. Each of the 31 filled milk formulations was evaluated for flavor, odor, mouth-feel characteristics and overall acceptability utilizing the formulation containing coconut oil as a reference. Those formulations which were considered to have undesirable characteristics were excluded from further investigation. The emphasis of this stage was placed on selecting the top four filled milk formulations. The selections were based primarily on the mean scores for each of the four sensory characteristics evaluated and the comments gathered from the members of the sensory panel, and therefore no statistical analysis was conducted. The stage-one approach was used as a screening tool. From stage one, four formulations possessing the best mouth-feel, odor and flavor characteristics were selected for further investigation.

In the second stage, the four formulations selected were processed and evaluated. A randomized complete block design was utilized. In addition to the sensory evaluation, the formulations were also analyzed for fat separation, lipid oxidation, and microbiological qualities. The storage stability of the formulations was determined over a three week period. From the stage-two approach the top two formulations with the best storage stability profiles were selected and further evaluated organoleptically in stage-three.

In stage-three, the combination of oil and emulsifier/stabilizer with the best overall characteristics (mouth-feel, flavor and odor) was determined.

C. Processing Outline

During preliminary investigation, filled milk formulations (10 gallons) were vat-pasteurized at 145°F for 30 minutes and homogenized through a Mantin Gaulin 50 GPH, two stage homogenizer (APV Gaulin Inc., Everett, MA). The pressure settings of the first and second stage were 2000 and 500 psi, respectively (Arenson, 1969).

For the second stage and remainder of the study, a 200-gallon vat with a circulating pump system was used to blend the four formulations of ingredients . Each of 30 gallon formulation was then processed through a De Laval 460 GPH HTST pasteurizer (De Laval Brand, Alfa-Laval Agri Inc., Everett, MA) and homogenized through a single stage homogenizer (APV Crepaco Inc., Rosemont, IL) at 2000 psi (Arenson, 1969).

The filled milk samples were filled in one-half gallon plastic containers using a plastic bottling machine (Federal Mfg. Co., Milwaukee, WI) and stored in a cooler kept at 35°F in

D. Analytical Methods

1. TBA Test for Lipid Oxidation

The levels of lipid oxidation of vegetable oils in products were monitored by means of the thiobarbituric acid (TBA) test (King, 1962). Filled milk samples (17.6 ml) were pipetted into flasks fitted with a glass stopper. The milk samples were warmed to 86°F (30°C), and one ml of trichloroacetic acid (TCA) solution (containing one gram per ml) was added, followed by two ml of 95% ethanol and shaken vigorously for 10 sec. After five minutes, the contents were filtered through a No. 42 Whatman filter paper. To four ml of the clear filtrate, one ml of TBA solution was added, mixed, and placed in a 140°F (60°C) water bath for 60 minutes. The filtrate was cooled, and the absorbance determined at 532 nm with a Spectonic 1001 spectrophotometer (Bausch & Lomb, Rochester, NY) using distilled water as a reference. TBA values were taken every three days for a three-week period during which the storage stability of the samples was determined.

2. Fat Separation

The extent of fat separation of the filled milk formulations was determined by the Farrall Homogenization Index (Goss, 1953; Farrall et al., 1941). A stage microscope was used to standardize an eyepiece disc ruled in such a manner that the fat globules were able to be measured in microns and half-microns. One milliliter of filled milk was diluted with 25 ml of 40% glycerine solution. A droplet of the diluted sample was placed on a slide with a well. A cover glass was then placed over and pressed lightly into place. After 15-20 minutes, the fat globules were examined under the microscope. Five different fields selected at random were examined and the fat globules over two microns were counted. The index of homogenization was determined by multiplying the total number of globules recorded for each size group by the factor (k) for that group. To evaluate further the performance of the emulsifier/stabilizer system, as well as the homogenization efficiency, a test commonly used in the dairy industry was also run where fat separation was determined by assessing the amount of fat which migrated to the top (10%) of a graduated cylinder containing 1000 ml of milk and compared to the levels of fat which remained in the bottom (90%) of the graduated cylinder. A difference in readings of more than 10% would suggest that there was considerable fat separation occurring in the milk.

3. Microbial Tests

Standard plate counts (SPC) and coliform violet red bile (VRB) tests were run on all milk formulations both at day one and five after processing (Richardson, 1985).

4. Sensory Evaluation

Milk formulations were evaluated on the following characteristics: off-flavors and odors, mouth-feel, overall milk flavor, and overall acceptability. The scales utilized were

Milk formulations were evaluated on the following characteristics: off-flavors and odors, mouth-feel, overall milk flavor, and overall acceptability. The scales utilized were the following:

Off-flavors/odors ..... 1=none; 5=extreme
Overall milk flavor ..... 1=very poor; 9=excellent
Mouth-feel ..... 1=very poor; 5=excellent
Acceptability ..... 1=unacceptable; 9=extremely acceptable

These sensory characteristics and scales were adapted from the American Dairy Science Association scorecard used for evaluating milk samples (Bodyfelt et al., 1988). The sensory panel consisted of present and past members as well as the coach of the Kansas State University Dairy Product Judging Team, and faculty knowledgeable in evaluation of milk. To be familiar with off-flavors and odors from vegetable oils, the panelists were trained with filled milk samples following the dairy product judging team training procedure (Bodyfelt et al, 1988). For each session of sample analysis, the panelists were instructed to follow the milk judging procedures (Bodyfelt et al., 1988). They were encouraged to make additional comments for other sensory characteristics. An average of seven panel members served on each panel for the stage one experiment, and five members participated for the remainder of the study. Products were tempered to 60°F before evaluation.

5. Statistical Analysis

The sensory data were computed for least-squares means using SAS General Linear Models (GLM) Procedures (SAS, 1985).

RESULTS AND DISCUSSION

Stage-one: The goal of the first stage of this study was to select two or possibly three combinations of oil and emulsifier/stabilizer which would have the greatest potential of replacing coconut oil. These combinations were selected by evaluating sensory characteristics of the prepared filled milk samples using a trained taste panel. A total of 31 formulations were evaluated for the four parameters described previously. Results of the evaluations are shown in Tables A-3, A-4, A-5 and A-6.

Based on mean scores of four sensory parameters as well as panel comments (Tables A-3-A-6), three oils were selected for further investigation from 31 formulations tested. The three oils selected in decreasing order of preference were the following: Trisun HB95 (SVO Enterprises), Canola (Anderson Clayton/Humko) and partially hydrogenated Cottonseed oil (Beatrice/Hunt Wesson). Trisun HB95, Canola, and Cottonseed oil performed best with Actoloid D22A, Actoloid D22B and Mono- & diglycerides, and Actoloid D22C,

the batch pasteurization process used. In formulations containing vegetable oils such as Kaomel, Duromel, Sunflower HB 105, and natural sunflower oil with 0.2% added tocopherol, off-flavors such as "oily" and "beany" overpowered the cooked flavor (See panel comments in Tables A-3, A-4, A-5, and A-6). The "oily" off-flavor was described as resembling that of cooking oil in the mouth and was a major off-flavor lessening the product acceptability. Bundus (1970) reported that whenever oil-in-water emulsifying agents were employed in a filled milk formulation, the flavor and mouth-feel were lacking in rich taste and the product tasted "watery" and "oil-like." However, when water-in-oil emulsifiers were used, the filled milk formulation had a rich, full flavor, possessing creaminess and, at the same time, less of an "oily" taste. These results suggest that the type of emulsifier affected the milk flavor as we observed with the formulation containing Sunflower HB 95 (Table A-7). It appears that in formulations containing cottonseed oil, the type of emulsifying agent affected the flavor/odor and, ultimately, the acceptability of the product (Table A-8).

Not all formulations containing sunflower oil possessed as pronounced an oily flavor, however. Results from sensory evaluation suggested that formulations with Sunflower HB 95, Canola and Cottonseed oils did not possess as strong of an oily flavor as the rest of the formulations tested. Formulations containing Sunflower HB 105, Kaomel, Duromel, and natural sunflower oil with 0.2% added tocopherol were characterized as having a "chalky" mouth-feel, including canola oil when used in combination with Actoloid D22C (Table 5). This defect became noticeable as the milk sample was placed in the mouth but became more prominent once the sample left the mouth, leaving a sensation of dryness in the mouth.

All the work done in the preliminary study was based on minimum allowed standards for solids (8.25%) and fat (3.25%) (CFR, 1991). Many of the defects in formulations observed during stage-one study seen throughout the rest of the study (See Tables 3, 4, 5 and 6 for lists of specific defects). However, it was noted that HTST pasteurization greatly reduced the extent to which these defects were noticed. Furthermore, an increase in the percent solids was considered to possibly "mask" some of the less pronounced but more common defects observed in the formulations such as "oily flavor."

Some of the other defects noted in certain formulations included the chalky mouth-feel as in the case of Trisun HB105. This defect was sensed during and after the sample had left the mouth, leaving a dry sensation in the mouth. On the other hand, there were some formulations which, besides having the chalky mouth-feel, also exerted a pronounced oily flavor. These defects were observed mostly in formulations containing Sunflower oil with 0.2% added tocopherol, Kaomel and Duromel.

Stage-two: The stage-two studies involved further evaluation of the four formulations selected: HB95/Actoloid D22A, Canola/Actoloid D22B, Canola/Mono- & diglycerides and Cottonseed/Actoloid D22C. In this part of the study, all products were pasteurized with a HTST heat exchanger and homogenized at 2500 psi using a single-stage homogenizer.

Cottonseed/Actoloid D22C. In this part of the study, all products were pasteurized with a HTST heat exchanger and homogenized at 2500 psi using a single-stage homogenizer.

Results of the physicochemical analysis suggested that all batches of products tested were stable during storage at 2°C. The Farrall Index of Homogenization ranged from 4.2 to 13.6. Considering that a Farrall Index of 12 is considered to be a satisfactory limit (Doan and Mykleby, 1943), the homogenization in this study appeared to be sufficient to disperse the vegetable oils into the milk proteins and to network them with the emulsifiers and stabilizers used. No visual fat separations were observed during storage. The TBA analysis indicated that lipid oxidation was negligible in all four formulations during storage (Table A-9). All formulations containing the partially hydrogenated oils showed an absorbance of less than 0.035 during three weeks of storage, and none of the formulations showed significantly higher TBA values ($P < 0.05$) than the formulation containing coconut oil. Furthermore, no members of the sensory panel reported oxidized off-flavor. Microbial counts were low during three weeks of storage. Both SPC and coliform counts were well below the legal limit for Grade "A" pasteurized milk and milk products (PMO, 1989).

As shown in Table A-10, all formulations had "slight" off-flavors as indicated by the mean scores when evaluated at 15°C. However, none of the panelists indicated any major off-flavor or odor problems. Similar results were observed previously with these formulations during preliminary studies. According to the comments made by panelists, however, some differences were noticed in the off-flavor/odor characteristics among the four formulations. The formulation with Cottonseed/D22C was characterized as being "aromatic," "flowery," or "perfumery" in nature. The formulation containing Sunflower HB 95/D22A possessed few off-flavors/odors during the first week of storage. After two weeks, however, an "oily" off-flavor/odor became more pronounced. Meanwhile, formulations containing Canola/Mono- & diglycerides or Actoloid D22B did not have any identifiable off-flavors. During three weeks of storage, the formulation with Canola/D22B possessed the lowest mean scores for off-flavors/odors among the four formulations, although differences were not statistically significant.

Table A-11 shows sensory results for overall milk flavor of the four formulations during three weeks of storage. They indicated that the formulation containing Sunflower HB 95/D22A possessed a significantly better milk flavor than formulations containing Cottonseed/D22C or Canola/Mono- & diglyceries after the first week of storage and also showed a higher mean than Canola/D22B. After two weeks of storage, however, the Sunflower HB95/D22A formulation possessed less milk flavor intensity, partly from the loss of some of the full, creamy milk flavor characteristics and partly from the development of a persistent oily flavor. The formulation containing Canola/D22B, on the other hand, received consistently high milk flavor scores during three weeks of storage. The overall mean values suggest that the formulation with Canola/D22B had the most acceptable milk flavor among the four formulations, although the difference was not statistically significant.

Table A-12 indicates that all four formulations had acceptable mouth-feel. There

were no statistically significant differences among the formulations. The highest mean scores were observed for the formulation containing Sunflower HB 95/D22A after the first week of storage. However, it did not retain these high scores. The Canola/D22B formulation showed consistently higher mean values during three weeks of storage. According to the panel comments, all four formulations had a slight "chalky" mouth-feel, but it was not regarded as a major defect.

As shown in Table A-13, the overall acceptability of the four formulations followed the same pattern observed in the other three sensory characteristics for which these filled milk samples were evaluated. The mean values after one week of storage were highest for the formulation containing Sunflower HB 95/D22A, but declined after two weeks of storage. The mean values suggest that the degree of acceptability of the formulation with Sunflower HB 95/D22A improved minimally, but not significantly at three weeks of storage. The formulations containing Canola/Mono- & diglyceries and Canola/D22B showed an improvement from week one to week two of storage. However, Canola/D22B retained its level of acceptability after three weeks of storage, whereas the formulation with Canola/Mono- & diglycerieds dropped considerably in its acceptability (Table A-13).

Examination of the sensory data collected over the three weeks of storage suggests that formulations with Canola/D22B and Sunflower HB 95/D22A were better than the other two formulations. After the first week of storage, the two formulations were characterized as having acceptable mouth-feel and little off-flavors and/or odors. They also were comparable to one another in overall milk flavor. However, the latter formulation did not retain its milk flavor during the rest of storage. The formulation with Canola/D22B showed much more consistency in off-flavor, overall milk flavor, and acceptability.

Stage-three: Above results suggested that there might be a possibility of improving the overall milk flavor as well as other parameters by blending oils. Therefore, the blend of oils which was formulated and evaluated was a 50/50 blend of Canola and Sunflower HB95. The emulsifiers used were also a 50/50 blend of Actoloid D22A and Actoloid D22B. During the storage stability test after one week of storage, it was noted that HB95/D22A scored more preferable than any of the other formulations for off-flavor/odors, overall milk flavor, mouth-feel and overall acceptability but the scores dropped considerably after two and three weeks of storage. Thus by combining the qualities of HB95/D22A and those of Canola/D22B, the resulting blend might display characteristics which would provide for a high acceptance and good storage stability product.

The 50/50 blend was evaluated over a two-week period on the same four parameters previously mentioned. The scores were evaluated and compared against scores obtained for Canola/D22B, Canola/Mono- & diglycerides, HB95/D22A and Cottonseed/D22C. The results are summarized in Tables A-14 & A-15. Most of our efforts were directed toward evaluating how the 50/50 blend performed against Canola/D22B since it was the formulation with the best overall characteristics.

described as being somewhat creamier than the other formulations resembling the characteristics seen in fresh cow's milk.

CONCLUSIONS AND RECOMMENDATIONS

Of the eight vegetable oils and the four emulsifiers/stabilizers tested, the top four formulations which performed the most favorably are (in decreasing order) Canola/D22B, Canola/Mono- & diglycerides, HB95/D22A and Cottonseed/D22C. Both Canola formulations had the least amount of off-flavors and odors, and possessed an acceptable mouth-feel and milk flavor as well. Cottonseed/D22C is characterized by being too aromatic which was desirable to some, but undesirable to others. HB95/D22A performed rather well except for the one defect which was the characteristic of oily flavor. The formulation containing HB95/D22A performed better than any other formulation after one week of storage, but steadily decreased thereafter.

It is our opinion that a **blend of HB95/D22A with Canola/D22B** at a 1:1 ratio is the most acceptable product. The second desirable product is Canola/D22B. The Canola/mono- & diglycerides is also acceptable. Because the size of the panel used, we were not able to determine statistical significance among many of the samples although considerable differences in mean sensory scores were observed. Therefore, we recommend that a user's test be conducted at the Government Owned Contractor-Operated plant locations for the final selection of a formulation.

This document reports research undertaken at the U.S. Army Natick Research, Development and Engineering Center and has been assigned No. NATICK/TR-93/004 in the series of reports approved for publication.

REFERENCES

Arenson, S. W. 1969. Imitation dairy products; their formulation, processing and quality control. Food Eng. 41(4):76-81.

Bodyfelt, F.W., Tobias, J., and Trout, G.M. 1988. *The Sensory Evaluation of Dairy Products*. 140-206. Van Nostrand Reinhold, New York, NY.

Bundus, R.H. 1970. Filled milk product. U.S. patent 3,488,198, January 6.

CFR 1991. Code of Federal Regulations, Title 21. Section 131.110. U.S. Government Printing Office, Washington, DC.

Doan, F.J. and Mykleby, R.W. 1943. A critical study of the United States Public Health Service definition for homogenized milk with some recommendations. J. Dairy Sci. 26:893-907.

Farrall, A.W., Walts, C.C., and Hanson, R.L. 1941. Homogenization index as calculated from measurements of fat globule size. J. Dairy Sci. 24:539 (Abstract).

Goss, E.F. 1953. Fat in homogenized, chocolate, evaporated, and sweetened condensed milks. Ch. 6, in *Techniques of Dairy Plant Testing*, C.K. Johns (Ed.), p. 120. The Iowa College Press, Ames, IA.

King, R.L. 1962. Oxidation of milk fat globule membrane material. I. Thiobarbituric acid reaction as a measurement of oxidized flavor in milk and model systems. J. Dairy Sci. 45:1165-1172.

Kinzel, B. 1990. Frozen milk - low cholesterol, tastes great. Agri. Res. 38(4):19.

Lane, D. 1986. The story of Fit 'n' Lite. Food Manufacture May:27.

Mann, E.J. 1988. New Products. Dairy Industries International 53(12):10-11.

Modler, H.W., Rippen, A.L., and Stine, C.M. 1970. Physical and chemical stability of soybean oil filled milk. J. Food Sci. 35:302-305.

PMO 1989. Grade "A" Pasteurized Milk Ordinance. U.S. Department of Health and Human Services, Public Health Service/Food Drug Administration. U.S. Government Printing Office, Washington, DC.

Richardson, G.H. 1985. *Standard Methods for the Examination of Dairy Products.* 15th ed., 133-150; 173-187. American Public Health Association, Washington, DC.

SAS 1985. *SAS® User's Guide: Statistics, Version 5 Edition,* SAS Institute, Inc., Cary, NC.

APPENDIX
FOR
TABLES

Table A-1. List of vegetable oils tested.

Vegetable oil	Source
Partially Hydrogenated Soybean	Anderson Clayton/Humko
Partially Hydrogenated Canola	Anderson Clayton/Humko
Partially Hydrogenated Coconut	Anderson Clayton/Humko
Partially Hydrogenated Sunflower (Trisun HB 95[2])	SVO Enterprises
Partially Hydrogenated Sunflower (Trisun HB 105[2])	SVO Enterprises
Natural Sunflower[3]	SVO Enterprises
Duromel[1,2]	Durkee Industrial Food Corp.
Kaomel[1,2,4]	Durkee Industrial Food Corp.
Partially Hydrogenated Cottonseed	Beatrice/Hunt-Wesson

[1]Partially hydrogenated

[2]Trade name.

[3]Sunflower natural is not hydrogenated; it contained 0.2% tocopherol.

[4]A 50/50 mixture of partially hydrogenated cottonseed and soybean oils.

Table A-2. List of emulsifiers and/or stabilizers tested.

Emulsifier/Stabilizer	Source
Mono- & diglycerides	Anderson Clayton/Humko
Actoloid D22A[1]	Advanced Food Systems
Actoloid D22B[2]	Advanced Food Systems
Actoloid D22C[3]	Advanced Food Systems

[1]A mixture of mono- and diglycerides, sodium caseinate, soy protein, carrageenan, and sodium citrate.

[2]A mixture of mono- and diglycerides, soy protein, whey protein, carrageenan, sodium citrate, and disodium phosphate.

[3]A mixture of mono- and diglycerides, sodium caseinate, carrageenan, and sodium citrate.

Table A-3. Mean sensory scores for filled milk formulations containing Actoloid D22A.

Formulation	Sensory characteristics			
	Off-flavor[1]	Milk flavor[2]	Mouth-feel[3]	Acceptability[4]
Sunflower HB 95[5]	1.83	7.17	3.97	6.67
Sunflower HB 105[6]	2.17	6.17	4.00	5.50
Cottonseed[7]	2.17	5.33	3.50	5.25
Sunflower (natural)[8]	3.29	4.43	3.29	4.29
Soybean[9]	2.43	5.86	3.43	5.29
Canola[10]	2.14	5.86	3.86	5.86
Kaomel[11]	3.50	3.86	2.50	2.71
Duromel[12]	2.93	4.79	2.50	4.00

[1]Off-flavor/odor scale: 1= none; 5 = extreme.
[2]Overall milk flavor scale: 1 = very poor; 9 = excellent.
[3]Mouth-feel scale: 1 = very poor; 5 = excellent.
[4]Acceptability scale: 1 = unacceptable; 9 = extremely acceptable.

Panel comments (summary):
[5]Oily flavor; cooked.
[6]Slight chalky mouth-feel; slightly oily flavor; cooked.
[7]Slight oily flavor and odor; chalky mouth-feel.
[8]Strong oily flavor; beany flavor; cooked.
[9]Strong oil flavor; beany flavor; cooked.
[10]Slight oily flavor; sweet; cooked.
[11]Strong oil flavor; chalky mouth-feel; cooked.
[12]Oily flavor and odor; chalky mouth-feel; cooked.

Table A-4. Mean sensory scores for filled milk formulations containing Actoloid D22B.

Formulation	Sensory characteristics			
	Off-flavor[1]	Milk flavor[2]	Mouth-feel[3]	Acceptability[4]
Sunflower HB 95[5]	2.14	5.71	3.26	6.40
Sunflower HB 105[6]	1.80	6.60	4.00	6.40
Cottoonseed[7]	1.80	6.40	3.80	6.00
Sunflower (natural[8])	3.60	3.00	2.80	2.80
Soybean[9]	2.00	6.00	3.86	5.71
Canola[10]	2.00	6.00	3.86	6.00
Kaomel[11]	2.40	4.40	3.40	4.00
Duromel[12]	2.60	4.80	3.40	4.20

[1]Off-flavor/odor scale: 1 = none; 5 = extreme.
[2]Overall milk flavor scale: 1 = very poor; 9 = excellent.
[3]Sensory scale: 1 = very poor; 5 = excellent.
[4]Sensory scale: 1 = unacceptable; 9 = extremely acceptable.

Panel comments (summary):
[5]Oily flavor; cooked.
[6]Slight chalky mouth-feel; cooked.
[7]Oily flavor pronounced (tallowy); cooked.
[8]Strong oxidized flavor; metallic off-flavor.
[9]Slight oil flavor; chalky mouth-feel; cooked.
[10]Slight oil aftertaste; cooked.
[11]Strong oily flavor; slick mouth-feel; cooked.
[12]Slight oxidized; very aromatic (perfumery); cooked.

Table A-5. Mean sensory scores for filled milk formulations containing Actoloid D22C.

Formulation	Sensory characteristics			
	Off-flavor[1]	Milk flavor[2]	Mouth-feel[3]	Acceptability[4]
Sunflower HB 95[5]	2.67	5.00	4.00	4.67
Sunflower HB 105[6]	2.50	6.00	3.75	5.50
Cottonseed[7]	1.75	7.25	4.25	7.25
Sunflower Natural[8]	4.50	2.75	2.50	1.50
Soybean[9]	1.50	6.83	4.33	7.00
Canola[10]	2.67	5.83	3.83	5.50
Kaomel[11]	2.75	5.25	3.50	5.00
Duromel[12]	2.00	6.00	3.50	6.25

[1]Off-flavor/odor, scale: 1 = none; 5 = extreme.
[2]Overall milk flavor, scale = 1 = very poor; 9 = excellent.
[3]Scale: 1 = very poor; 5 = excellent.
[4]Scale: 1 = unacceptable; 9 = extremely acceptable.

Panel comments (summary):
[5]Oily, cardboardy flavor; chalky mouth-feel; cooked.
[6]Slight metallic; cooked.
[7]Slight oily flavor; cooked
[8]Oxidized, oily, beany flavor; cooked.
[9]Lacks body; cooked.
[10]Slight oily flavor; chalky mouth-feel; cooked.
[11]Lacks body; slight soapy; cooked.
[12]Lacks body; cooked.

Table A-6. Mean sensory scores for filled milk formulations containing mono- & diglycerides.

Formulation	Sensory characteristics			
	Off-flavor[1]	Milk flavor[2]	Mouth-feel[3]	Acceptability[4]
Sunflower HB 95[5]	2.91	5.91	3.71	5.97
Sunflower HB 105[6]	2.61	5.50	3.50	5.25
Cottonseed[7]	2.49	5.77	3.43	5.33
Soybean[8]	2.89	5.88	3.51	5.89
Canola[9]	2.01	5.90	3.68	5.95
Kaomel[10]	2.60	3.78	2.51	2.90
Duromel[11]	2.79	4.37	2.61	3.35

[1]Off-flavor/odor, scale: 1 = none; 5 = extreme.
[2]Overall milk flavor, scale: 1 = very poor; 9 = excellent.
[3]Scale: 1 = very poor; 5 = excellent.
[4]Scale: 1 = unacceptable; 9 = extremely acceptable.

Panel comments (summary):
[5]Oily mouth-feel; cooked.
[6]Oily, painty mouth-feel; cooked.
[7]Slight oily flavor; cooked.
[8]Atypical flavor; cooked.
[9]Oily mouth-feel; cooked.
[10]Atypical mouth-feel; cooked.
[11]Strong oily flavor; cooked.

Table A-7. The effect of the type of emulsifying/stabilizing agents on sensory characteristics of formulations containing Sunflower HB 95[1].

Emulsifying agent	Sensory characteristics			
	Off-flavor/ odor	Overall milk flavor	Mouth-feel	Overall acceptability
Actoloid D22A	1.83[a]	7.17[a]	3.97[a]	6.67[a]
Actoloid D22B	2.14[a]	5.71[ab]	3.28[a]	6.40[ab]
Actoloid D22C	2.67[a]	5.00[b]	4.00[a]	4.67[b]
Mono- & di glycerides	2.91[a]	5.91[ab]	3.71[a]	5.97[ab]

[1]Mean values from five panel membrs.

[ab]Scores with different superscripts within columns differ ($P < 0.05$).

Table A-8. The effect of the type of emulsifying/stabilizing agents on sensory characteristics of formulations containing Cottonseed oil[1]

Emulsifying agent	Sensory characteristics			
	Off-flavor/ odor	Overall milk flavor	Mouth-feel	Overall acceptability
Actoloid D22A	2.17[a]	5.33[a]	3.50[a]	5.25[b]
Actoloid D22B	3.49[ab]	6.40[a]	3.80[a]	6.00[ab]
Actoloid D22C	1.75[b]	7.25[a]	4.25[a]	7.25[a]
Mono- & di-glycerides	2.49[b]	5.77[a]	3.43[a]	5.33[ab]

[1]Mean values from five panel members.

[ab]Scores with different superscripts within columns differ ($P < 0.05$).

Table A-9. Average thiobarbituric acid (TBA) values for three trials during three weeks of storage.

	Vegetable oil/stabilizer				
Time (day)	Coconut/ Mono-& di[1]	HB95/ D22A[2]	Canola/ D22B[2]	Canola/ Mono-& di[1]	Cottonseed/ D22C[2]
1	0.022	0.044	0.034	0.027	0.035
4	0.055	0.017	0.012	0.035	0.010
8	0.067	0.023	0.018	0.035	0.017
11	0.039	0.033	0.021	0.037	0.021
16	0.053	0.030	0.021	0.034	0.023
20	0.035	0.015	0.011	0.033	0.016

[1]A mixture of mono- & diglycerides.

[2]Actoloid (a mixture of stabilizers and emulsifiers). See Materials and Methods for the composition.

Table A-10. Off-flavors/odors of four filled milk formulations containing partially hydrogenated vegetable oils and stabilizers (least-squares mean ± standard deviation)[1,2]

	Formulations			
Time (wk)	Cottonseed & Stabilizer C[3]	Sunflower & Stabilizer A[3]	Canola & Emulsifier M[4]	Canola & Stabilizer B[3]
1	2.45 ± 0.98	1.85 ± 0.59	2.44 ± 0.50	2.05 ± 0.70
2	2.44 ± 0.82	2.54 ± 0.67	2.14 ± 0.45	2.04 ± 0.83
3	2.22 ± 0.92	2.34 ± 0.66	2.66 ± 0.66	1.90 ± 0.63
Mean	2.37 ± 0.89	2.24 ± 0.65	2.41 ± 0.56	2.00 ± 0.72

[1]Mean of triplicates from 3 batches; Sensory scale (1 = none; 5 = extreme)

[2]Absence of superscripts within a row indicates no significant difference ($P > 0.05$).

[3]A mixture of emulsifiers and stabilizers. For their designation and composition, see Materials and Methods.

[4]A mixture of mono- and diglycerides

Table A-11. Overall milk flavor of four milk formulations containing partially hydrogenated vegetable oils and stabilizers (least-squares mean ± standard deviation)[1,2]

	Formulations			
Time (wk)	Cottonseed & Stabilizer C[3]	Sunflower & Stabilizer A[3]	Canola & Emulsifier M[4]	Canola & Stabilizer B[3]
1	$5.69^{cde} \pm 1.38$	$7.35^{a} \pm 1.70$	$5.90^{cde} \pm 1.72$	$6.52^{abc} \pm 1.54$
2	$5.64^{cde} \pm 1.88$	$5.64^{cde} \pm 1.17$	$6.94^{ab} \pm 1.22$	$7.04^{ab} \pm 1.24$
3	$6.00^{cde} \pm 1.47$	$6.10^{cde} \pm 1.06$	$5.15^{de} \pm 1.19$	$6.46^{abcd} \pm 1.26$
Mean	5.78 ± 1.57	6.36 ± 1.50	6.00 ± 1.52	6.67 ± 1.34

[1]Mean of triplicates from 3 batches; Sensory scale (1 = very poor; 9 = excellent)

[2]Mean scores within a row with different superscripts differ at $P < 0.05$.

[3]A mixture of emulsifiers and stabilizers. For their designation and composition, see Materials and Methods.

[4]A mixture of mono- and diglycerides

Table A-12. Mouth-feel scores of four filled milk formulations containing partially hydrogenated vegetable oils and stabilizers (least-squares mean ± standard deviation)[1,2]

	Formulations			
Time (wk)	Cottonseed & Stabilizer C[3]	Sunflower & Stabilizer A[3]	Canola & Emulsifier M[4]	Canola & Stabilizer B[3]
1	3.66 ± 0.74	4.19 ± 0.79	3.96 ± 0.77	4.01 ± 0.84
2	3.75 ± 1.20	3.75 ± 0.83	4.05 ± 0.67	4.35 ± 0.81
3	3.62 ± 0.87	3.94 ± 0.80	3.97 ± 0.70	4.01 ± 0.95
Mean	3.68 ± 0.95	3.96 ± 0.79	3.99 ± 0.70	4.12 ± 0.86

[1]Mean of triplicates from 3 batches; Sensory scale (1 = very poor; 5 = excellent)

[2]Absence of superscripts within a row indicates no significant difference ($P > 0.05$).

[3]A mixture of emulsifiers and stabilizers. For their designation and composition, see Materials and Methods.

[4]A mixture of mono- and diglyceride.

Table A-13. Acceptability of four filled milk formulations containing partially hydrogenated vegetable oils and stabilizers (least-squares mean ± standard deviation)[1,2]

	Formulations			
Time (wk)	Cottonseed & Stabilizer C[3]	Sunflower & Stabilizer A[3]	Canola & Emulsifier M[4]	Canola & Stabilizer B[3]
1	5.98 ± 1.83	7.24 ± 1.79	5.91 ± 1.79	6.59 ± 1.35
2	5.42 ± 2.38	5.22 ± 1.09	6.82 ± 1.03	6.92 ± 1.30
3	5.31 ± 2.05	5.61 ± 1.18	4.69 ± 0.92	6.23 ± 1.18
Mean	5.57 ± 2.08	6.02 ± 1.55	5.61 ± 1.56	6.57 ± 1.27

[1]Mean of triplicates from 3 batches; Sensory scale (1 = unacceptable; 9 = extremely acceptable)

[2]Absence of superscripts within a row indicates no significant difference ($P > 0.05$).

[3]A mixture of emulsifiers and stabilizers. For their designation and composition, see Materials and Methods.

[4]A mixture of mono- and diglycerides

Table A-14. Comparison of Canola/Sunflower HB 95 (50/50 mix) and four other formulations (mean scores for Trial 1/Weeks 1 and 2)

	Sensory characteristics			
Formulation	Off-flavor[1]	Milk flavor[2]	Mouth-feel[3]	Acceptability[4]
Cottonseed/D22C	2.44[s]	5.77[s]	3.84[ns]	5.87[s]
HB95/D22A	1.94[ns]	6.94[ns]	4.17[ns]	6.64[ns]
Canola/Mono-	2.42[s]	6.29[ns]	4.14[ns]	6.20[ns]
Canola/D22B	1.94[ns]	6.90[ns]	4.29[ns]	6.89[ns]
Canola/HB95	1.90	7.70	4.70	7.80

[1]Off-flavor/odor, scale: 1 = none; 5 = extreme.

[2]Overall milk flavor, scale: 1 = very poor; 9 = excellent.

[3]Scale: 1 = very poor; 5 = excellent.

[4]Scale: 1 = very poor; 9 = excellent.

[s, ns]Refer to differences compared against Canola/HB95 mixture, where (s) = significant difference at $P < 0.05$ and (ns) = no significant difference at $P < 0.05$.

Table A-15. Comparison of Canola/Sunflower HB 95 (50/50 mix) and four other formulations (mean scores for Trial 2/Weeks 1 and 2)

Formulation	Sensory characteristics			
	Off-flavor[1]	Milk flavor[2]	Mouth-feel[3]	Acceptability[4]
Cottonseed/D22C	2.40[s]	5.80[ns]	3.80[ns]	5.90[ns]ns
HB95/D22A	2.40[ns]	6.30[ns]	4.00[s]	6.10[ns]
Canola/Mono-	2.10[ns]	6.80[ns]	4.10[ns]	6.80[ns]
Canola/D22B	2.10[ns]	6.90[ns]	4.30[ns]	6.90[ns]
Canola/HB95	1.90	7.70	4.70	7.80

[1]Off-flavor/odor, scale: 1 = none; 5 = extreme.

[2]Overall milk flavor, scale: 1 = very poor; 9 = excellent.

[3]Scale: 1 = very poor; 5 = excellent.

[4]Scale: 1 = unacceptable; 9 = extremely acceptable.

[s, ns]Refer to differences compared against Canola/HB95 mixture, where (s) = significant difference at $P < 0.05$ and (ns) = no significant difference at $P < 0.05$.

DISTRIBUTION LIST

	NO. OF COPIES
Administrator Defense Technical Information Center Alexandria, VA 22314	2
Technical Library U.S. Army Natick Research, Development and Engineering Center Natick, MA 01760-5000	5
Commander U.S. Army Natick Research, Development and Engineering Center ATTN: SATNC-WTP (Andy Senecal) Natick, MA 01760-5018	30
DOD Joint Technical Staff U.S. Army Natick Research, Development and Engineering Center	
ATTN: SATNC-TAA	1
ATTN: SATNC-TAF	1
ATTN: SATNC-TAD	1
ATTN: SATNC-TAN	1
ATTN: SATNC-TAM Natick, MA 01760-5018	1
HQ USAF/MW Pentagon Washington, DC 20330-0001 ATTN: Brig. Gen. Lezy	1
HQ AFMWRSA/CL Randolph AFB, TX 78150-7000 ATTN: Col. Hunneycutt	1
Malcolm Grow USAF Medical Center/SGF Andrews AFB, DC 20331-5300 ATTN: Lt. Col. Walker	1
HQ AFMWRSA/MWHB Randolph AFB, TX 78150-7000 ATTN: Ms. Leslie	1
HQ AFMWRSA/MWHB Randolph AFB, TX 78150-7000 ATTN: Mr. Walt Hall	1